IoT in Education: Integration of Objects with Virtual Academic Communities

Jack Marquez[1], Jhorman Villanueva[1], Zeida Solarte[1], Alexander Garcia[1],

[1] Universidad Autonoma de Occidente, Calle 25 No 115-85,
760030 Cali, Colombia.
{jdmarquez, javillanueva, zsolarte, agdavalos}@uao.edu.co

Abstract: Internet has changed the way people interact and education has not been immune to this change, which has created new forms of interaction between teachers and students that helps to improve the teaching and learning process, and expands the context in which students learn. Moreover, with the integration of objects to the Internet, new possibilities for applications and services in domains such as education are available, where its use can lead to innovations that could facilitate the teaching-learning process. In this paper a new model for integrating objects to Virtual Academic Communities (VAC) is proposed. Tests of the proposed model were performed by the implementation of a case study, and the outcomes show that using IoT provides a more engaging learning environment for students and more data about the learning process to help teachers to enhance their knowledge about the learning pace of their students and their learning difficulties.

Keywords: Virtual Academic Communities, IoT, Architecture, learning process, education.

1 Introduction

Technology is one of the elements that have strongly influenced education in recent years, particularly since the Internet boom. Today we live in an era where the amount of data, knowledge and technological devices are changing the mindset of institutions in their teaching and learning processes. Taking technology as one of its tools, education is changing from a model by which knowledge is only transmitted to one where it is presented in an active and collaborative manner, seeking to improve the processes of teaching and learning.

Students acquire knowledge more easily if they do so interactively, i.e. where the activities actually motivate them to learn. Technology presents this great feature to get the attention of people and can be a great help in the teaching and learning process.

The Internet of Things (IoT), is barely being integrated into the application domain of education. This integration of technology shows great potential to enhance the teaching-learning process, providing support to make real the premise "anytime

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anywhere", not only in the common areas of education, taking advantage of the possibility of having a fully transparent and connected environment for the user.

The connection of objects in an educational environment can produce large amounts of data, such as when students are using educational resources, how they are using them, if they are really evolved and how many of them (through evaluation). Additionally, the integration of objects to the Internet or the Internet of Things opens new possibilities for applications in domains such as education, where its use can lead to innovations that enhance the teaching-learning process.

The inclusion of the IoT in the teaching-learning process enables the interaction between objects that are available in educational environments and students, and teachers. However, the integration of objects in the education domain is an issue that must be further researched because previous research works have focused primarily on aspects such as: network communications (protocols, technologies, etc.), objects identification, and architectures, among others.

This paper presents a new model for integrating objects that are available in educational environments with Virtual Academic Communities (VAC). One of the changes is that objects go from being passive elements in educational environments to becoming more active objects and more involved in supporting the teaching-learning process.

An adapted architecture is proposed for implementing this new integration model. This architecture is basically an adaptation of previous architectures for some IoT application domains, and it uses the paradigm of layered architectures and architectural styles such as REST architectures.

The rest of the paper is organized as follows. Section 2 reviews the background on the IoT in education; Section 3 proposes a new integration model of objects available in learning environments with Virtual Academic Communities (VAC). Section 4 presents an adapted architecture for implementing the new model. Section 5 presents a case study, which was proposed to test the new model. Section 6 discusses the outcomes of the test and Section 7 presents conclusions.

2 IoT in the Education Domain

Some research studies are looking to integrate the IoT in educational environments in order to improve the learning process and facilitate the teaching process, because according to these research studies the interaction of students with real-world objects promotes improved learning and understanding of a particular subject matter. Integrating IoT as a new actor in educational environments can facilitate the interaction of people (students and teachers) and (physical and virtual) objects in the academic environment. This interaction means that objects can communicate with each other and with the people who are in these educational environments.

Below are listed (see Table 1) some of the most relevant publications that were found in the literature on the application of the IoT in education through various works, researches and some case studies.

Table 1. Classification of publications on the application of IoT in education

Reference	Description	Differences
[1]	Interactive model based on IoT for English teaching.	This model is specific for English teaching and it use voice and visual sensors, which can correct English learners' shape of mouth and pronunciation.
[2]	IoT environment to teach elementary programming skills.	This research combines three concepts: IoT, Living Labs, and intelligent Campus (iCampus).
[3]	Lifelong learning environment using IoT and learning analytics.	The system use tagged objects and LMS for collecting data and performing the analysis of students' learning process using learning analytics techniques.
[4]	Ubiquitous learning environment using IoT.	Authors designed a technical framework and the system architecture of u-learning. Framework includes three layers: perception, network, and application layer.
[5]	Environments equipped with IoT devices to create new learning scenarios.	A system that allows students to interact with physical objects, which are virtualy associated with a subject of learning.

2.1 Objects in Educational Environments

Commonly in educational environments such as classrooms and laboratories, among others, there exist a number of physical objects (laboratory equipment, computers, books, collectibles, etc.) that are provided for the daily use of students and teachers to perform different teaching and learning activities. Integrating these objects to the VAC would allow additional types of activities that contribute to facilitating the teaching and learning processes.

Currently interaction with physical objects can be seen as static, since it implies that students perform processes manually requiring them to be in the same place as the object. While the integration of objects to the VAC could make this interaction more dynamic, because these may generate additional data to students and teachers, allowing interaction between them that is both virtual and autonomously, and supporting the teaching and learning activities in a more direct way.

The IoT has played an important role in the integration of the physical and virtual worlds. Integrating physical objects can help to improve services/applications, and thus processes, such as education, can be enriched with more data and new forms of interaction that help to generate more integrated educational environments and facilitate teaching-learning activities.

3 Integration Model of Objects to VAC

The Virtual Academic Community, VAC, is formed by one or more groups of individuals linked by common interests, committed to continuous learning processes, whose main objective is the shared construction of knowledge, using ICT as a means of expression, as a communication tool, as a teaching resource and even as a management tool [10]. These are the possibilities of communication and interaction that are generated in the VAC, the determinants that have facilitated its position as a resource of great demand for building knowledge and learning collaboratively.

The intention to integrate objects to the VAC is that they become active elements (physically and virtually) inside the VAC and allow supporting communication activities, teaching, learning, monitoring and management, among others. Having a characterization and differentiation of such objects, allows evaluating and understanding the level of intervention and involvement in space, time and forms of interaction that are foreseen.

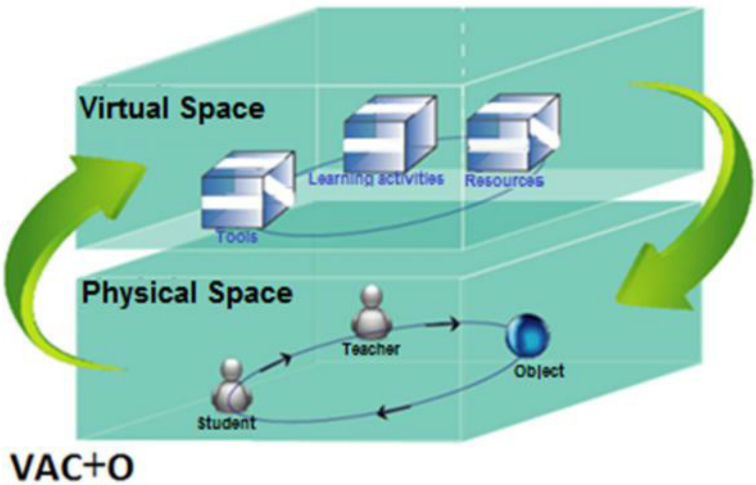

Fig 1. VAC spaces: virtual and physical

Differentiation of these spaces is related to the space, in which the objects exist, which may be physical or virtual (see Fig. 1). The first is the physical place where actors that make up the VAC, such as the teacher (tutor) or teachers share and live. In this space are located physical objects belonging to the environment (classroom, laboratory, libraries, auditoriums, etc.).

A virtual space (see Fig. 1) is a non-physical space that is not tangible, for which the categories of time and position are not possible. It is specifically designed for the interaction of people and for the processing, storage, distribution and exchange of information. Some of the best known virtual spaces are social networks, chat rooms, discussion forums and email.

Regarding the VAC, it is clear that the elements that support it, are located in the virtual space, where tools like blogs, forums and chat rooms are found; the contents in different formats (text, image, audio/video) that are generated and consumed; and learning activities designed to be performed by students individually or collectively (see Fig. 1). The virtual object par excellence in the learning environment is the LMS (Learning Management System), which is a learning management platform where the services and tools such as authentication, administration, evaluation, communication, and collaboration, among others are integrated. Below are briefly described the actors and elements that compose these two spaces (physical and virtual):

a) Physical space: In this space coexist the physical actors that make up the VAC, they can generate content and interact with other actors, as follows:

- Teacher: is responsible for teaching a particular topic and designs the learning activities.
- Student: is responsible for participating in learning activities that can be collective or individual which may involve the use of and interaction with objects.
- Objects: are the physical objects that are found in different educational environments like laboratory equipment (e.g. measuring instruments, tools), books, textbooks, desks, and boards, and so on. These objects facilitate the work of students and teachers and allow them to carry out the activities of learning / teaching.

b) Virtual space: in this space are the elements that support the VAC, as follows:

- Tools: typically, tools such as blogs, forums, chat rooms, etc., which together with the contents (text, image, audio / video) are used by the actors (students, teachers, objects) to make and facilitate teaching-learning activities.
- Contents: are elements such as text, images, audio, and video that are generated and consumed by the actors.
- Learning Activities: are the activities performed by the students, which can be collective or individual, and among them are: workshops, homework, lab

work, etc. The objects come to play an important role in these activities, because what is sought by integrating them to the VAC is to help facilitate the learning process and improve interaction with them.

3.1 Objects Classification

With regard to the objects that can be integrated into the VAC it is understood that they are those, which through unique addressing schemes can interact with other objects in order to achieve objectives set by design. In this sense, the classification of these objects ranges through the performance of any of the following categories of analysis [6], [7], [8]: level of interaction, processing capability, and intelligence. The following objects classification is proposed:

- Tagged Objects: are objects that are tagged using technologies such as RFID or NFC that hold information about them (codes, identification, description, etc.). They are also known as "Non-IP Objects", since they do not support Internet protocols and do not have an IP address.
- Smart Objects: they are endowed with certain computing capabilities, storage, and communications, which allow them to perform data processing and communicate with other objects and software platforms (e.g. send data about their status).
- Social Objects: now taking a generational leap from objects with "some intelligence" to objects with a certain "social awareness", thus resulting in the so-called "social objects" [9]. This type of object inherits the capabilities of smart objects and thanks to them they may be part of a community of objects and are able to relate to each other independently to cooperate in certain activities.
- Virtual objects: they are digital elements that have a specific purpose, comprise a series of data and can perform different actions. They are characterized by a very flexible level of interaction that allows them to interact through interfaces with people, applications/services or other objects.

These different types of objects can be integrated to a VAC (see Fig. 2) and become an active part of it, thanks to the possibilities of interaction that they offer. Integrating physical objects to the VAC seeks to take advantage of their specific qualities (physical and technical) to support and strengthen services and processes in terms of individual and collaborative construction of knowledge and learning; for this purpose the exchange of data between physical objects is very important, including between physical and virtual objects and between objects and people.

This is considered as a positive advance in relation to the forms of interaction in a VAC, as there is a broadening of possibilities because it is no longer just about the teacher-student and student-student or student interaction with tools, resources, content and learning activities; in short, the range is extended to integrate interaction with objects.

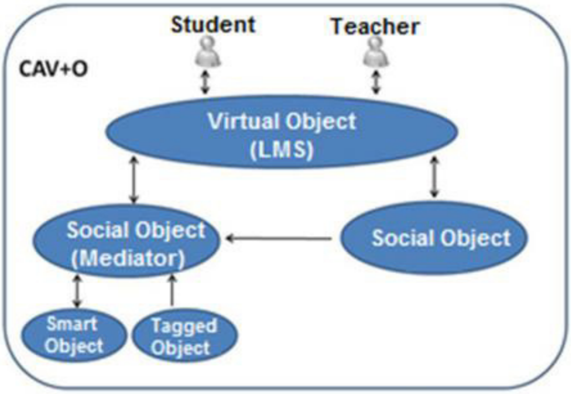

Fig 2. Objects integration and their relationship with VAC actors

4 Architecture for IoT in Education

To facilitate the implementation of the proposed model of integration an architecture that can be used to structure scenarios in educational settings was defined.

From the review of reference architectures for IoT [11], [12], [13], [14] and taking into account the principles of service-oriented architectures (SOA), an adaptation of an architecture that combines some previous architecture features was proposed.

IoT reference architecture allows real space objects to communicate and become part of the virtual space, while SOA can provide modularity and interoperability because it facilitates the implementation of services on different devices, and platforms, with the possibility that they interact.

The proposed architecture uses the paradigm of layered architectures and it consists of four layers, which are explained as follows:

- Hardware/Communications Layer: This layer has all the hardware components and communications that allow physical objects to be adapted or created so they can be part of the Internet.
- Messaging Layer: This layer is responsible for establishing communication between objects, more advanced than the hardware/communications layer, using a simple protocol of request-response, using the data that the hardware/communications layer makes available and turning it into messages.
- Services Layer: In this layer the services are offered, and they use the data captured by the objects to fulfil a specific purpose, only objects with IP

communication interfaces may offer services, so only those objects implement this layer. This layer works under a REST (REpresentational State Transfer) style, which uses HTTP protocol to make calls between machines instead of using complex mechanism such as SOAP (Simple Object Access Protocol).

- Application Layer: This layer is closest to the end user and consists of all applications that are implemented associated with specific scenarios. Each application must provide interfaces for user access to them. The applications are based on services offered by the service layer and the composition thereof.

5 Test of Proposed Integration Model

To test the integration model a digital electronics course for undergraduate engineering students was selected as a case study. In this course students have to implement a digital circuit and it is possible to collect data about lab work performed by the students.

In the proposed case study two objects have been implemented: a measuring instrument (smart object) and a Mediator (social object), and the LMS Moodle was adapted as a virtual object. Figure 3 shows a schematic diagram of the scenario with objects, the architecture layers which are implemented and interactions between the objects.

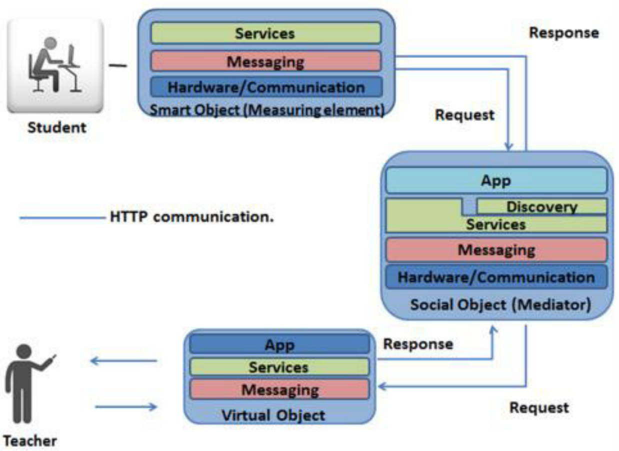

Fig 3. Testing scenario of the integration model.

The students interact with implemented objects (e.g. measuring element and mediator) at the lab for doing their tasks and the more relevant data of their activities (e.g. measurements) are collected and stored in the LMS Moodle database. Then the teacher can track this data through LMS reports, which helps the teacher to monitor the work that students have done in the lab.

The teachers can also track and analyse other issues such as the information (web pages, papers, blogs, etc.) recommended by students to their peers, the time that students take to solve the exercises in the lab, and monitor the students that access to the lab class.

For implementing and adapting the objects for testing the proposed model Arduino and Raspberry Pi boards were used, because they are two of the most common prototyping boards due to their openness and support (documentation, user community options, etc.).

6 Discussion

Two surveys were conducted to evaluate the case study, which was used for testing the implementation of the integration model:

a. Survey 1: questions about the "technological profile" of students on the course were defined. The questions focused on showing whether students had previous experience using technology (e.g. use of e-learning platforms) in previous courses and their participation in VAC.
b. Survey 2: questions about the students' perceptions of practical experience in the laboratory during the test were defined. The questions focused on the students' perception about the objects deployed in the laboratory, the VAC services and interaction using the VAC tools.

Survey 1 was conducted before the test with 13 students on the digital electronics course, while survey 2 was conducted after the test. The answers to both surveys' questions that were collected from students have been analysed and some interesting findings from correlating the two surveys are evident:

- Previous experience in the use of technology was not relevant for the test implementation of the integration model. That is, even though new objects and some adapted objects were deployed in the test scenario with their respective services objects, the use of these objects and their services was relatively easy for students and in the students' opinion (see Table 2), they helped to facilitate the implementation of the lab work.

Table 2. Two questions related to technological elements

Question	Always	Almost always	Almost never	Never
Were the devices deployed to support	61.5%	30.8%	7.7%	0%

the laboratory classes helpful for performing lab work activities?				
Was it easier to perform the laboratory class activities with this form of work supported by technology?	46.2%	53.8%	0%	0%

- The VAC and its services was a new element for the students of this course and its use positively contributed to the development of the activities of the lab class (see Table 3). The fact that students have the facility to handle services such as forums and chat rooms, and interact virtually through these tools allows them to easily adapt to the environment of the VAC and its services.

Table 3. Two questions related to VAC topics

Question	Always	Almost always	Almost never	Never
Did the collaborative activities (forums and discussions) in the VAC help to build knowledge?	23.1%	53.8%	15.4%	7.7%
Do you think that the VAC is a reliable learning environment?	46,2%	46,2%	7,7%	0%

- According to the opinion of students (see Table 4), the expectations they had about lab work were fulfilled and adding objects and technological elements motivated them to perform the activities in the lab class more easily.

Table 4. Two of the questions about students' expectations

Question	Always	Almost always	Almost never	Never
Did using technological elements in the setting of the lab class and virtual elements motivate you to perform the activities in the lab more easily?	76.9%	23.1%	0%	0%
Do you consider that your expectations of the lab class using VAC support were fulfilled?	61.5%	38.5%	0%	0%

According to the previous arguments it is possible to say that the perception of students of the test course is positive and based on their answers to survey 2 the deployment of (new and adapted) objects and VAC services helped them to perform the lab work activities.

7 Conclusions

This paper proposes a new model for integrating objects to VAC and an adapted architecture for implementing and testing this new model. The integration of smart objects to the VAC enables the gathering of more data about activities in labs and new ways of interaction between actors in the VAC and objects. The objects go from being passive elements in labs to becoming more involved in supporting the teaching-learning process.

The data gathered could help teachers to understand the learning process in more detail, which means that they can see which parts of an assignment of the lab work were easy and which parts were so difficult that the students experienced difficulty and could not achieve the learning goals. Teachers could use this data to improve their feedback to students and to be more accurate in their advice to students.

IoT could help to improve teaching and learning experiences, especially for courses that involve working in labs. And using the IoT in the teaching-learning process enables an interaction between smart objects that are available in educational environments and students and teachers. However, the interaction between objects is an issue that should be further researched and our future work will focus on this topic, which is also relevant for other application domains.

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